Alaska Fire Science Consortium
Research Brief

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Climate, Fire, Frost and the Carbon Bank

RESEARCH BRIEF:

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Manies studies biomass carbon stored in the forest floor.

LINKS:

http://carbon.wr.usgs.gov/

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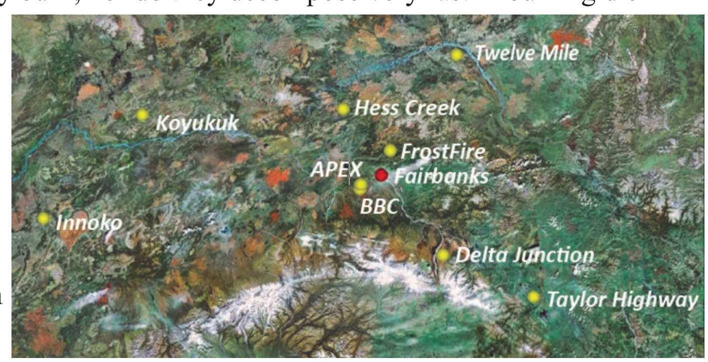
...working together to bridge the gap in boreal fire science delivery, outreach, and application.

Global climate models anticipate that climate warming will be most severe and occur earlier at high latitudes.[1] Since 1949, mean annual air temperatures and mean summer temperature in Alaska have increased twice as quickly as average global temperatures.[2] High-latitude regions also store nearly half of the world's organic carbon (C) pool in active-layer soils and permafrost[3], which may be sensitive to this recent warming.

US Geological Survey (USGS) scientists Jennifer Harden and Kristen Manies are interested in how climate change, reflected in changes in fire dynamics (season and severity) and permafrost thaw, will affect the **carbon cycle** in Alaska. You might call them the CPA's of the carbon bank! Cashing in the carbon stored in plant material, fossil fuels, and frozen soil could result in increased atmospheric CO_2 and markedly accelerate the pace of warming. On the other hand, there are many factors and feedbacks to consider. Maybe faster plant growth, for example, could make C "deposits" and offset these losses, keeping the C cycle near equilibrium, like it has been for thousands of years.

Harden and Manies began by looking at fire effects on organic layers and their C stores in interior Alaska (see image for some sampling sites). Warming climate has led to increases in the annual acres burned in Alaska.[4] Fires burned twice as much area between 2000-2010 than in any decade of the previous 40 years. And, because summer temperature is such an important driver of fire occurrence in boreal forest[5], the average area burned per year in Alaska is projected to double by the middle of this century.[3] The amount of C released by combustion in forest fires ranges from 5-30% of the C stored in above-ground plants and trees[4] (remember, the trunks of trees rarely burn, nor do they decompose very fast in our frigid climate)! But most of the carbon for these forests is stored in the forest floor. Under severe drought conditions, up to 90% of the C stored in the moss, duff, and organic soil can be released back to the atmosphere by combustion. Variability of matter consumed is high (±50%) because duff consumption depends on moisture content in the forest floor.



Most of the USGS Alaska study sites were located in upland black spruce stands on north-facing slopes, underlain by permafrost. Rates of C accumulation and loss were studied in stands of different ages ranging from recent burns to mature spruce stands >200 years old. The oldest sites in the study banked about 8 kg C/m^2, while recent burns on average held only 3 kg/m^2. Carbon storage in the forest floor increased very slowly with stand age with an overall "deposit" rate of 20–40 g C/m^2 annually—equivalent to one or two typical charcoal briquettes —for stand ages up to 200 years.[6]

Based on this simple formula, more frequent and/or deeper burning forest fires might be expected to decrease the average amount of C stored in the "bank" over time. However, when permafrost dynamics are considered, the results were surprising. Harden and Manies discovered that on the cold north-facing slopes of their study sites, the cycle of burning, thawing http://akfireconsortium.uaf.edu

This frozen soil core reveals layers of woody debris buried under moss at a site where permafrost re-developed after a fire.

Carbon 'Futures' in the Boreal Forest:

Climate warming will influence fires in the boreal forest of Alaska, first and most rapidly by influencing fire weather, and more gradually by affecting long-term water tables, soil drainage and active layers. Meanwhile, you might want to open a carbon savings account!

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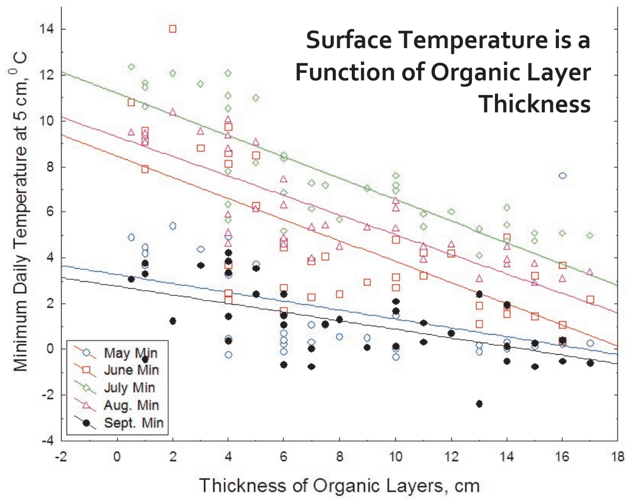
and re-freezing as the insulating moss and duff layers grew back pumped carbon deeper into the frozen landscapes. After a fire, woody debris became buried under regrowing moss and eventually transferred to the subterranean "freezer" as near-surface permafrost recovered: safe from decay or repeat burning events! Thus, these ice-rich sites continued to maintain—or even augment—their carbon stores, even with modest increase in fire frequency and severity, illustrating the resilience of this ecosystem.[3]

Harden in Alaska burn

However, the fate of C is different if permafrost degrades or disappears. The latest research suggests that dry summers are likely to increase the burning of thick peat layers in most uplands, resulting in thinner insulating organic soil layers and greater thawing of near-surface permafrost.[7] This cycle reduces the capacity of soils for C storage over the long-term.[3] If aspen and birch stands replace some of the spruce forest their rapid growth may store more C above ground, but probably not enough to balance the books with respect to the C lost from soils when the stand was spruce. Since the insulating moss/duff layer plays such a critical role in protecting permafrost, conditions suitable for the rapid regrowth of permafrost are key in determining whether boreal forest will retain its ability to store large amounts of carbon. Manies and Harden found seasonal thaw depth and organic duff depth were inversely related[8]. Even shallow moss mat temperatures (at 5 cm depth) dropped about 1°F for every cm added to the overall organic mat thickness (graph[8]).

In summary, the fate of the moss/organic soil layer in a warmer future environment is critical to projecting changes in fire regime and carbon banking. This is because this organic layer:

- **Governs the interface between the water table and vegetation and, therefore, water and nutrients available for plant growth,**
- **Provides thermal insulation between the atmosphere and mineral soils which, along with snow insulation, strongly influences seasonal thaw,**
- **Provides most of the ground fuels for large wildfires.**



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You can read more about Harden and Manies' work and view project data and related studies at their USGS website: http://carbon.wr.usgs.gov/data.html

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